PICS Normalization: Improved Temporal Trending Using PICS

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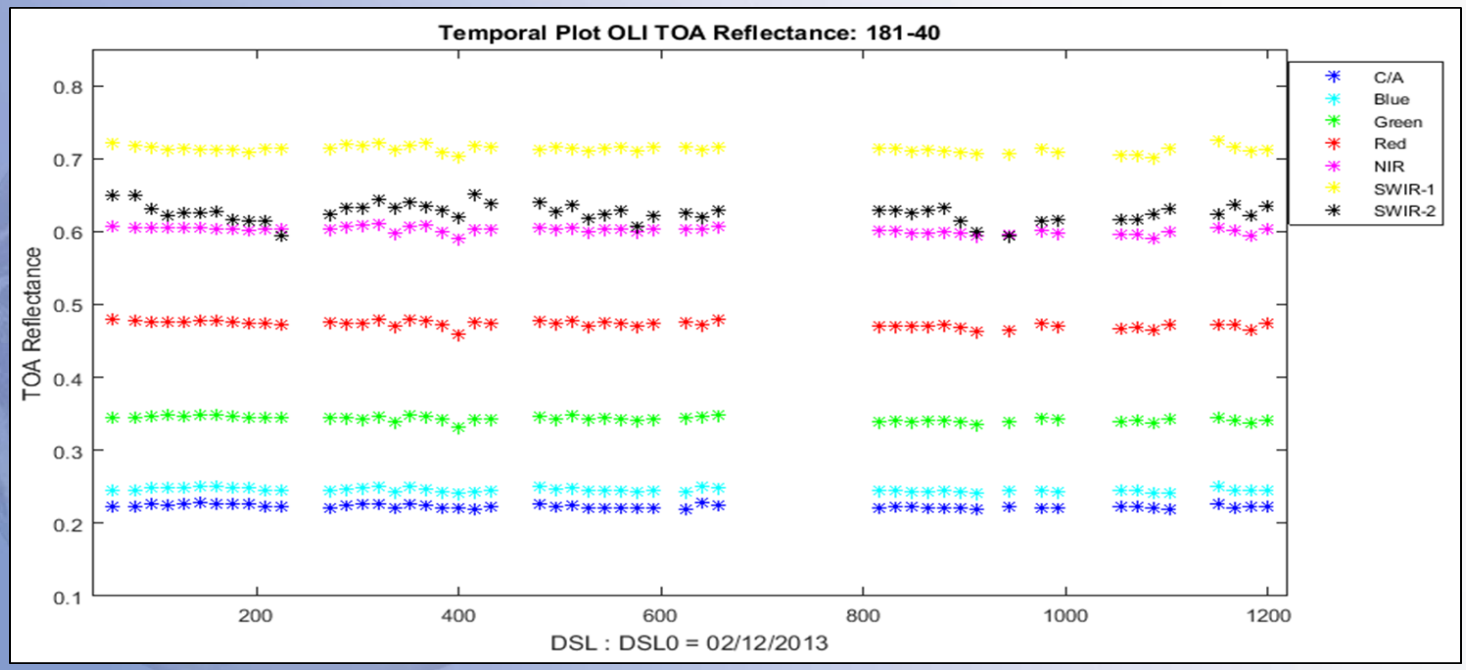
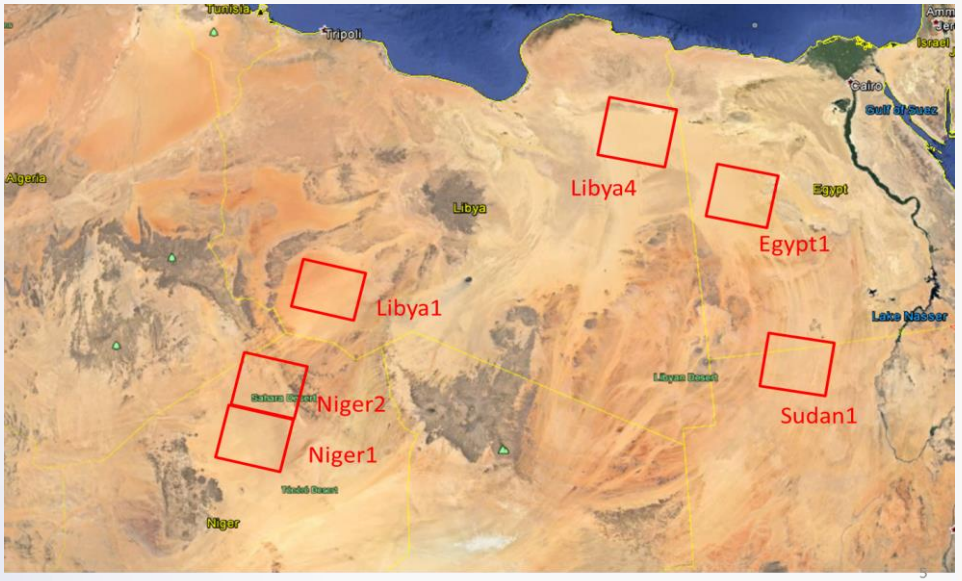
Background

- PICS (Pseudo Invariant Calibration Site) have been used for on-orbit radiometric trending of optical satellite sensors for many years,
- If the site is invariant, any change we see from the trending indicates the change in sensor responsivity.
- Highly regarded sites used by the calibration community are located in the Sahara desert, Northern Africa, i.e. well known-Libya4, Libya1, Egypt1, Niger1, Niger2, Sudan1



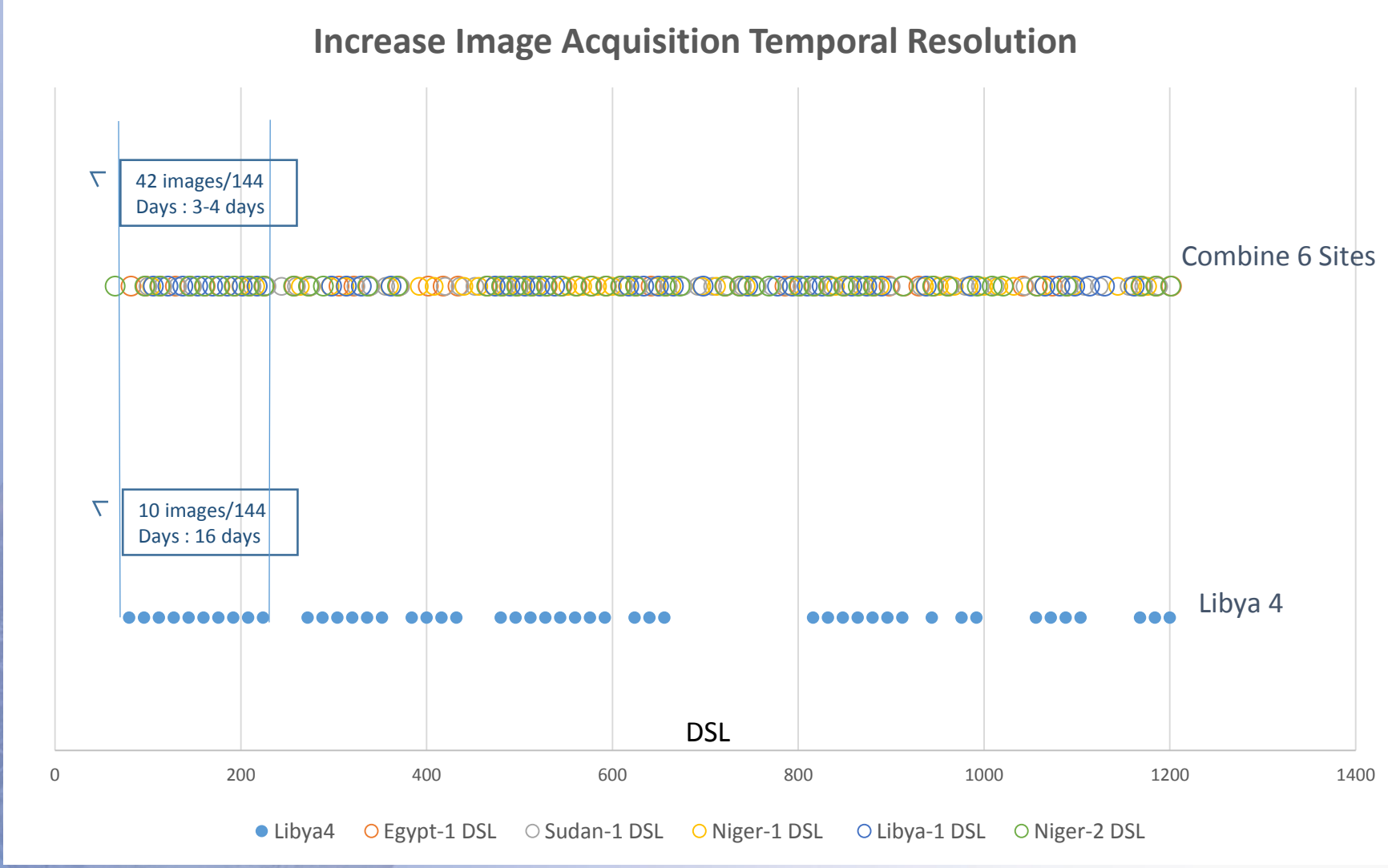
OLI-Bands	Temp. Uncertainty
Coastal	0.96%
Blue	0.92%
Green	0.83%
Red	0.78%
NIR	0.59%
SWIR-1	0.54%
SWIR-2	1.94%

Background



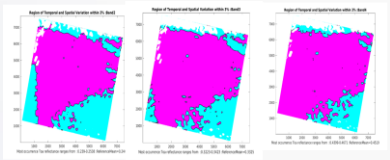
- Limitation on data acquisition
  - Every 16 days,
  - Cloudy scenes
- Recent study shows that small number of acquisitions (less than 3 years) not adequate enough to show sensor degradation
- New Approach: we use all 6 PICS site to increase number of data acquisitions, and align them together with reference to well-known Libya4
  - Increase temporal resolution of data acquisition
  - Normalize each site to Libya4

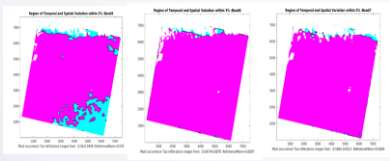
PICS Normalization: Increasing Temporal Resolution

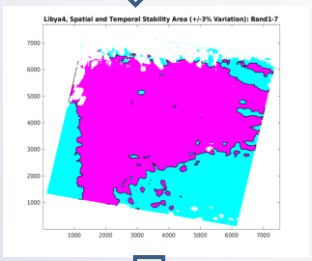


Scale factor to Libya4 = Optimal Reference Libya4 / Optimal Reference(PICS)

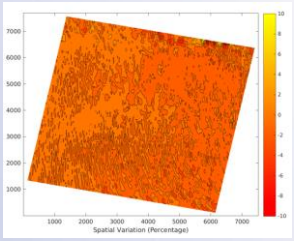
Find Optimal Stable Region :
3% Temporal and Spatial &Spectral







Find Optimal reference

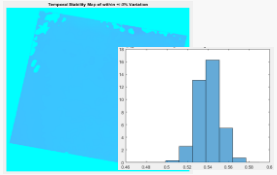


12months Images

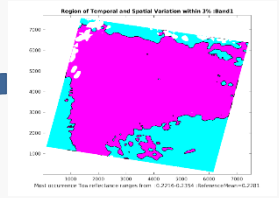
Convolution, Mean Map, Standard Deviation
Stability Map

Temporal Stability Map

3% Temporal Stability Mean Map



Histogram, range of TOA reflectance,
most occurred => SpatialTemporal Mean



Find 3% Temporal and Spatial variation
from Temporal Stability map

Libya4
-CorrectionMap

Libya1
- CorrectionMap
- Scale factor to Libya4

Niger1
- CorrectionMap
- Scale factor to Libya4

Niger2
- CorrectionMap
- Scale factor to Libya4

Egypt1
- CorrectionMap
- Scale factor to Libya4

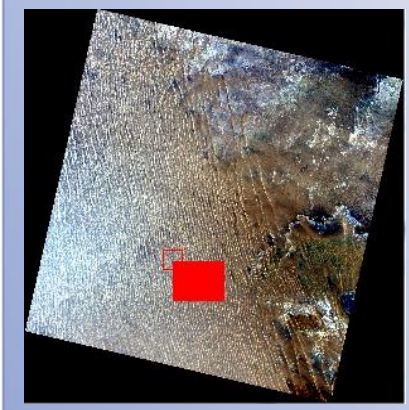
Sudan1
- CorrectionMap
- Scale factor to Libya4

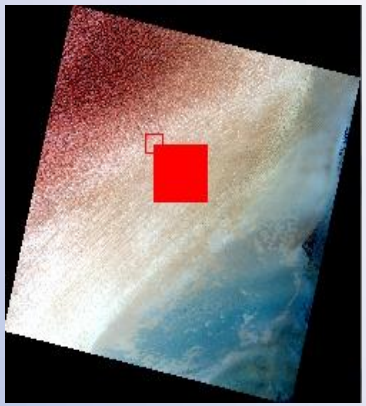
CorrectionMap : Normalized to Optimal Reference

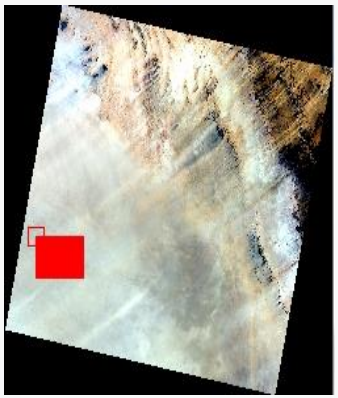
PROCEDURE
(Normalization within the PICS site)

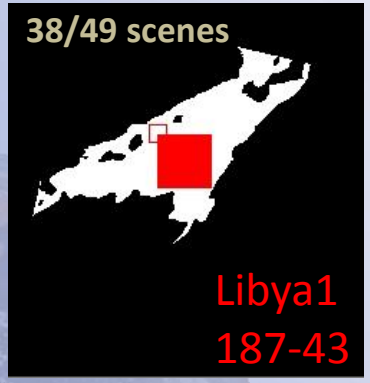
- Find optimal reference region: a 3% Spatially, Temporally and Spectrally stable region for each PICS site.
  - One year, 12 months Cloud Free images.
  - Perform smoothing filter to the images and stack the 12 smoothed images together.
  - Calculate temporal mean, standard deviation then calculate temporal uncertainties map.
  - Create a temporal stability mean map having 3% temporal uncertainty.
  - Use Histogram to find a range of TOA Reflectance most occurred in the 3% temporal stability mean map.
  - Take a mean of this range, call it 'Temporal Spatial Mean', then find pixels having TOA reflectance within 3% from 'Temporal Spatial Mean'.
  - Create a 3% Temporal and Spatial Stability Map.
  - Repeat the process for all the bands and combine the results to find a region having 3% spatial, temporal and spectral stability called 'OPTIMAL STABILITY REGION'.
  - Calculate the mean TOA Reflectance => 'Optimal Reflectance' of the PICS site.
  - Calculate correction Map for each image-month: Normalizing the smoothed image to the 'Optimal Reflectance'.

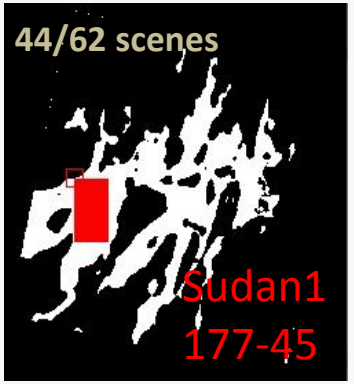
New ROI with SDSU Cloud Mask Filter

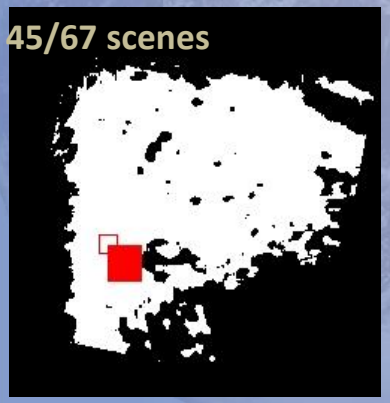


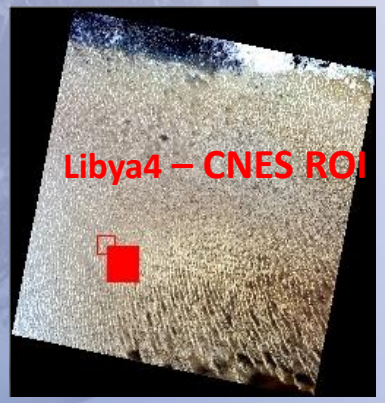








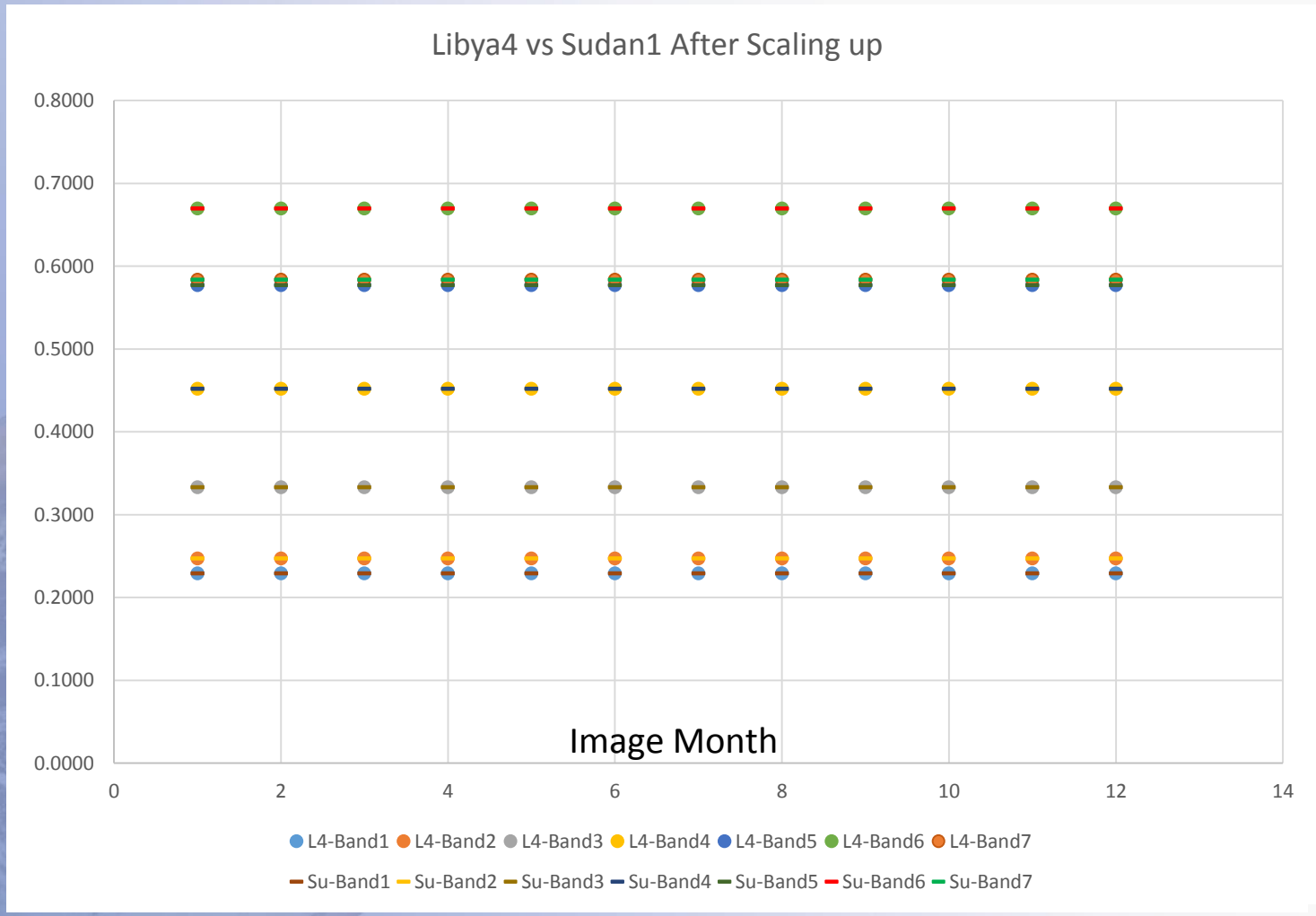




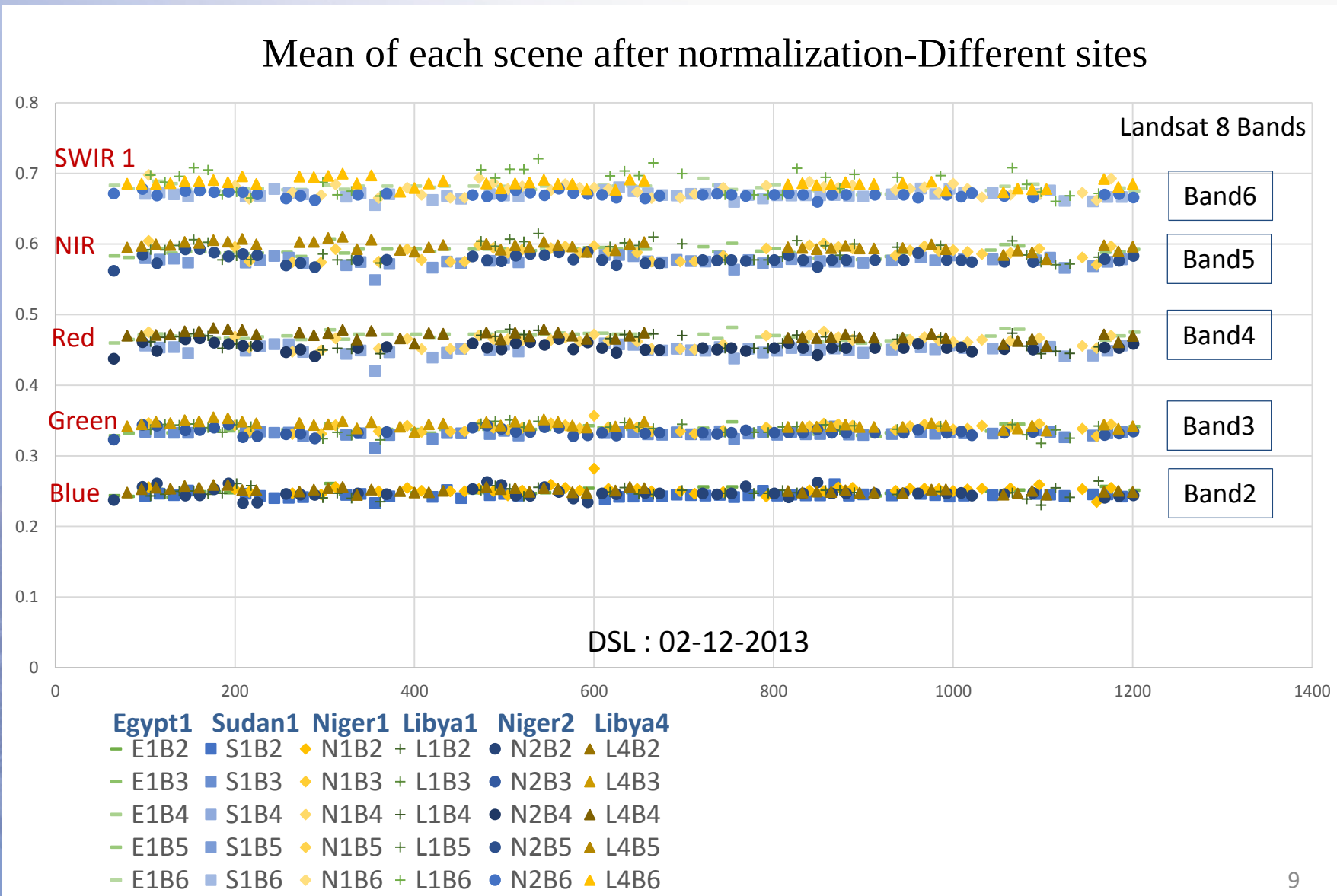
- White region : 3% Temporally, Spatially and Spectrally Stable region
- Red Region : New ROI for each PIC site from optimal stable area.
- SDSU Cloud Mask is used

PICS Normalization : ACROSS Sites

Smoothed Image (ROI) ✖ CorrectionMap (ROI) ✖ SF2Libya4 ➡ PICS Normalization

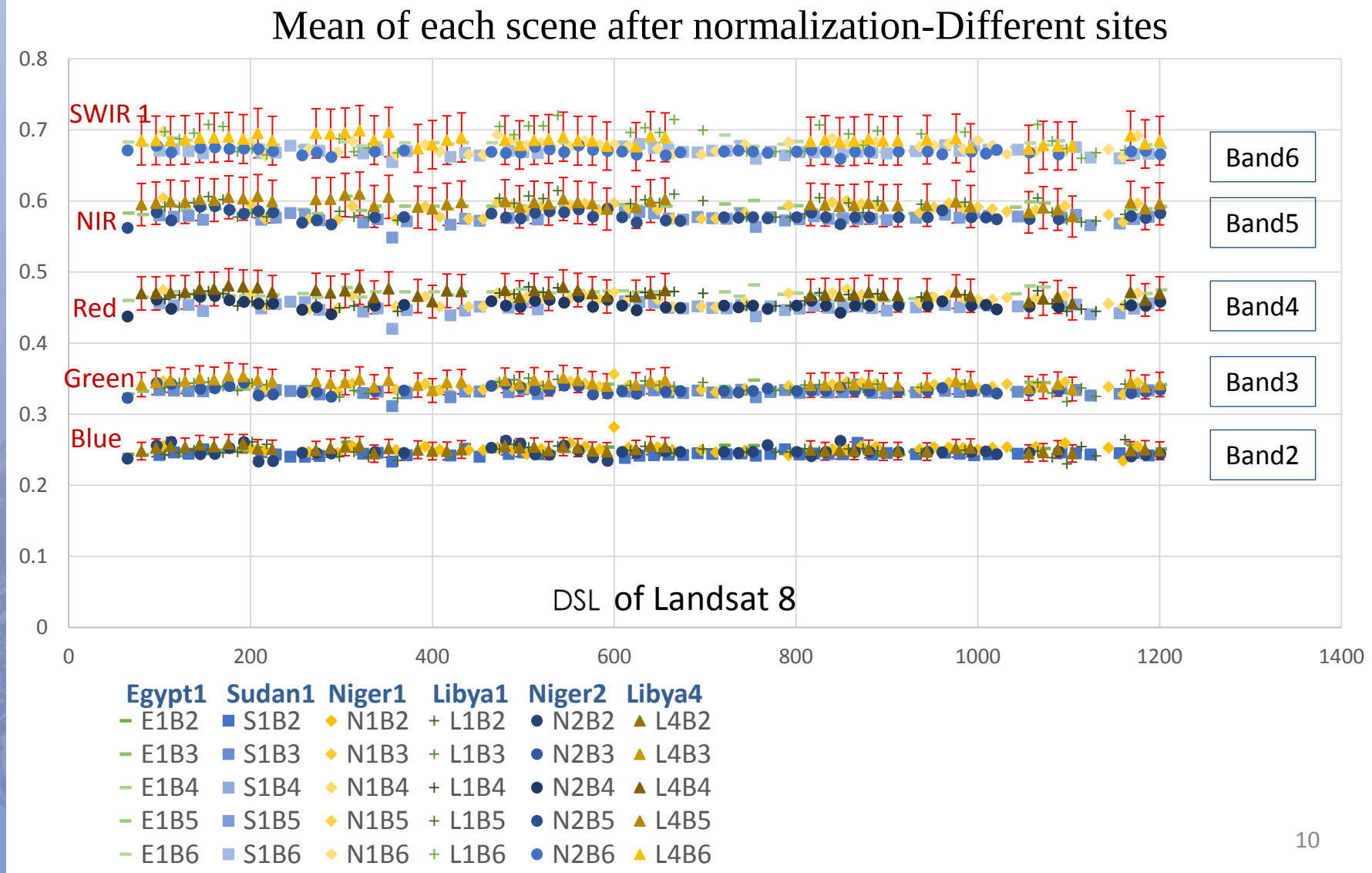


PICS Normalization : 6 PICS sites

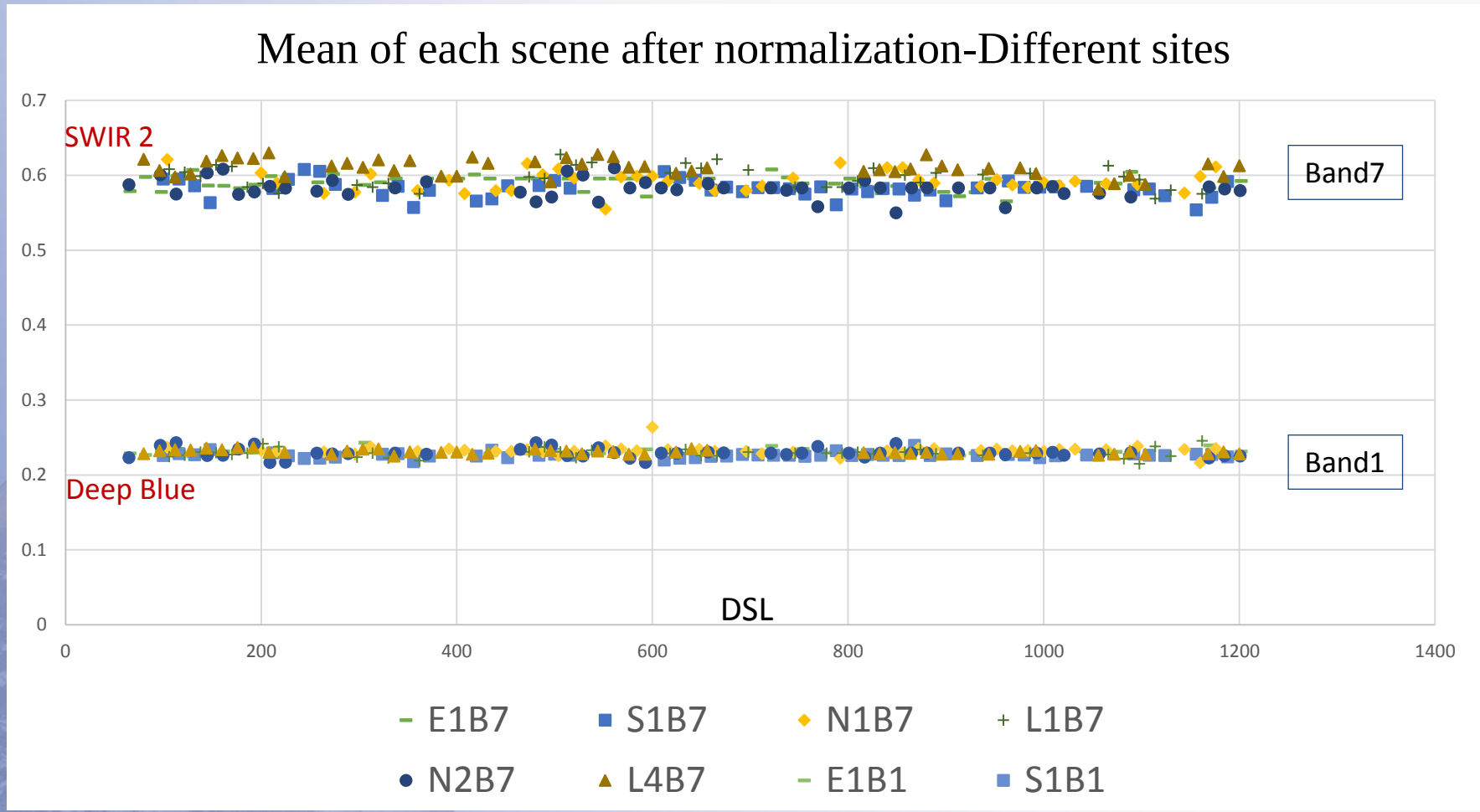


PICS Normalization: 6 PICS sites

Showing 5% Error bars on Libya4 –TOA Reflectance after PICS Normalization

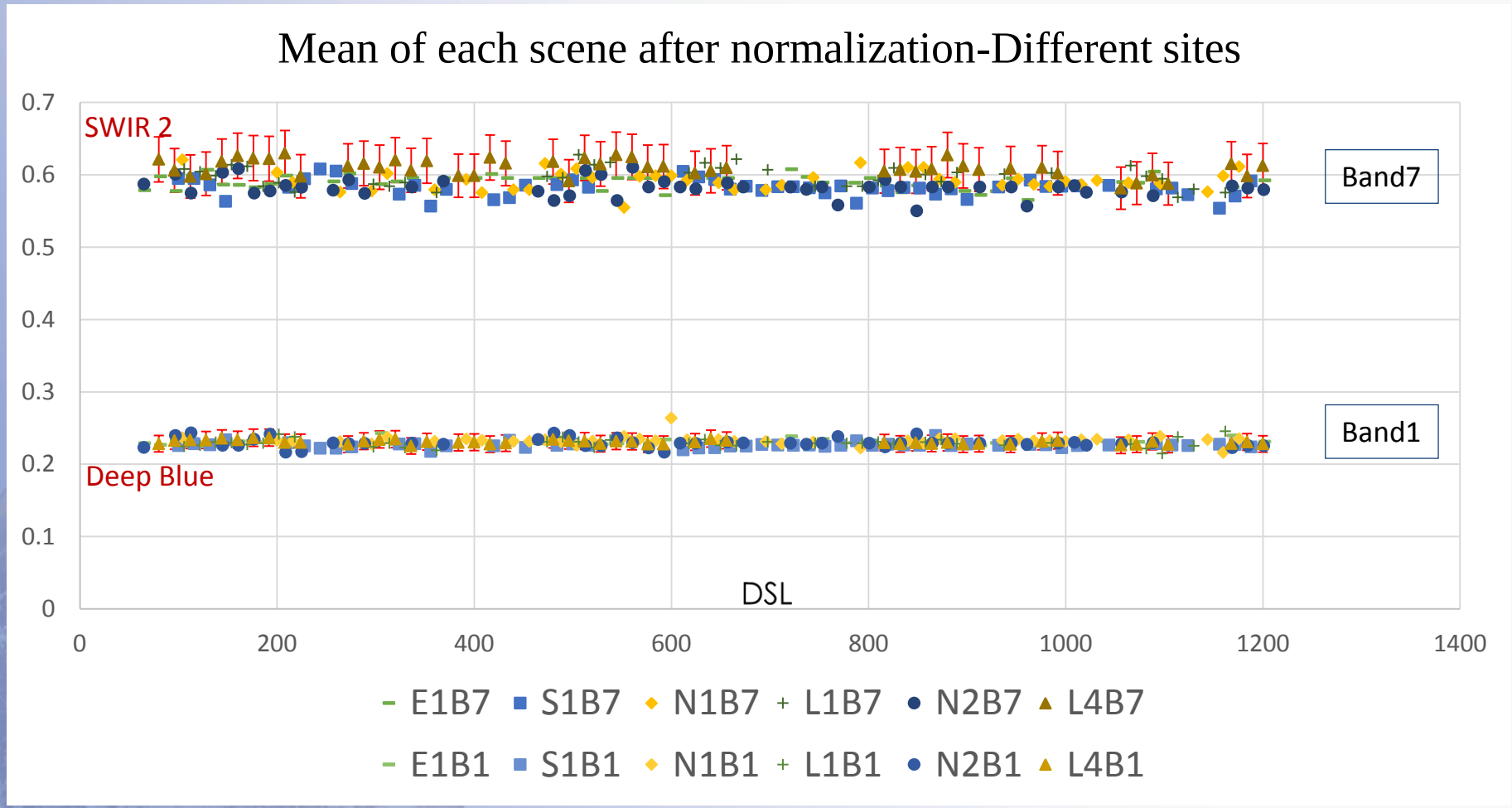


PICS Normalization : 6 PICS sites



PICS Normalization: 6 PICS sites

5% Error bars on Libya-4 Mean value after Normalization



Statistical Z-test : PICS Mean vs Libya4- After Normalization at 99% Confidence Level

	Band1	Band2	Band3	Band4	Band5	Band6	Band7
Libya4-Mean	0.2307	0.2510	0.3440	0.4700	0.5967	0.6857	0.6101
Libya-1	**Band1**	**Band2**	**Band3**	**Band4**	**Band5**	**Band6**	**Band7**
mean	0.2291	0.248	0.3384	0.4619	0.5907	0.6882	0.5980
Diff(L4 vs L1)	-0.69%	-1.20%	-1.63%	-1.74%	-1.01%	0.36%	-2.05%
Null Hypothesis	Accepted	Accepted	Rejected	Rejected	Rejected	Accepted	Rejected
Sudan-1	**Band1**	**Band2**	**Band3**	**Band4**	**Band5**	**Band6**	**Band7**
mean	0.2271	0.2448	0.3317	0.4501	0.5754	0.6677	0.5807
Diff(L4 vs S1)	-1.56%	-2.47%	-3.58%	-4.25%	-3.57%	-2.63%	-4.82%
Null Hypothesis	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected
Egypt-1	**Band1**	**Band2**	**Band3**	**Band4**	**Band5**	**Band6**	**Band7**
mean	0.2298	0.248	0.3363	0.4694	0.5896	0.6794	0.5905
Diff(L4 vs E1)	-0.39%	-1.20%	-2.24%	-0.15%	-1.19%	-0.92%	-3.21%
Null Hypothesis	Accepted	Rejected	Rejected	Accepted	Rejected	Rejected	Rejected
Niger-1	**Band1**	**Band2**	**Band3**	**Band4**	**Band5**	**Band6**	**Band7**
mean	0.2333	0.2522	0.3399	0.462	0.5879	0.6762	0.5918
Diff(L4 vs N1)	0.95%	0.32%	-1.31%	-1.79%	-1.53%	-1.31%	-2.93%
Null Hypothesis	Accepted	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected
Niger-2	**Band1**	**Band2**	**Band3**	**Band4**	**Band5**	**Band6**	**Band7**
mean	0.2292	0.25	0.3335	0.4534	0.5782	0.6695	0.5823
Diff(L4 vs N2)	-0.65%	-1.63%	-3.05%	-3.55%	-3.10%	-2.36%	-4.56%
Null Hypothesis	Accepted	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected

Future Work

- Refine the normalization process
- Expand PICS Normalization to longer time periods
- Include Atmospheric Model with PICS Normalization
- Apply PICS Normalization to other sensors to create additional calibration opportunities

THANK YOU